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Materiel Test Procedure 5-2-606
White Sands Missile Range

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

COMBINED STRUCTURAL ENVIRONMENTAL TESTS

1. OBJECTIVE

The objective of this MTP is to determine the effects of various simulated combined environments upon missile equipment and systems which are expected to experience these conditions during various periods of their normal operation.

2. BACKGROUND

Environmental testing is considered as being a somewhat expensive, but necessary, requirement in order to establish that the performance or life of an equipment, piece-part or component, will meet the required specifications. Environments can be grouped into three categories:

a. Natural environments, such as gravity and climatic conditions (temperature air pressure, rain, wind, biological and entomological attack).
b. Environments generated by enemy action, such as overpressure, earth or water shock, fragments from explosive heads, nuclear radiation, and electromagnetic interference.
c. Environments generated by the equipment or by interaction of the equipment with the surrounding medium, such as acceleration, vibration, chemical, electrical or kinetic heating, ionization, and aerodynamic excitation.

Of greatest concern to the environmental test engineer are the self-generated environments. Generally, these environments occur in combinations. Their effect upon systems and equipment will determine, to a large extent, the performance reliability of those systems and equipment to accomplish the mission for which they were designed.

Through combined structural environmental testing, conditions are produced in the "laboratory", which simulate the combined self-generated environments that the test item will experience during normal operation. With careful selection and control of test parameters, these tests provide vital data for evaluating the design and overall performance of systems and equipment in hostile environments.

3. REQUIRED EQUIPMENT

a. Still Camera with Film
b. As Required by the Individual Test Item:

1) Inspection fixtures and adapters
2) Inspection tools and equipment

c. As Required by the Applicable MTP's for the Tests Conducted:

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1) Test fixtures, jigs and adapters
2) Test facilities
3) Instrumentation
4) Shop handling equipment
5) Shop facilities

d. As required for rocket sled tests:

1) High-speed cameras with film
2) Still cameras (35 mm to 4 x 5 Speed Graphics) with film
3) Rocket Sled Test Facility (selected)
4) Data Acquisition Systems, including:

a) Photographic System(s)
b) Radio Telemetry System(s)
c) Wire Telemetry System(s)
d) Timing Systems
e) Sled Position and Velocity System
f) Data Monitoring Facilities

5) Test Item Instrumentation
6) Data Processing Facilities

4. REFERENCES

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L. MTP 5-2-504, Structural Testing for Nonoscillating, Steady-State and Transient Loads
M. MTP 5-2-506, Shock Test Procedures
N. MTP 5-2-507, Vibration Test Procedures

O. MTP 5-2-508, Acoustic Test Procedures
P. MTP 5-2-509, Aerodynamic Heating Test Procedures
Q. MTP 5-2-512, Missile System Aerodynamics Tests
R. MTP 5-2-582, Temperature-Altitude Test
S. MTP 5-2-583, Low Temperature Tests
T. MTP 5-2-586, Centrifuge Test Procedures
U. MTP 5-2-587, Photo-Stress Method of Structural Data Acquisition
V. MTP 5-2-593, High Temperature Tests with Solar Radiation
W. MTP 5-2-594, High Temperature Tests
X. MTP 5-1-025, Structural Data Analysis Methods
Y. MTP 5-2-607, Environmental Testing
Z. MTP 5-2-612, Aerodynamic Load Tests
A.A. MTP 5-1-028, Telemetry
A.B. MTP 5-1-029, Rocket Sled Tests

5. SCOPE

5.1 SUMMARY

This MTP describes a series of combined structural environmental tests which are conducted to simulate the various conditions which missiles and missile equipment are expected to experience during their normal operation. Criteria for the selection of test parameters, a discussion of special equipment and facilities required for the conduct of various tests, and a general discussion of combined environmental testing, are contained in the APPENDICES. The test procedures, themselves, are based on individual environmental tests considered in various combinations.

5.2 LIMITATIONS

The scope of this MTP shall be limited to "laboratory" testing which simulates the combined structural environmental conditions which missile systems, equipment, and components are expected to experience.

NOTE: Rocket sled tests are to be considered "laboratory" tests.

6. PROCEDURES

6.1 PREPARATION FOR TEST

a. Prior to testing, ensure that the following are available:

1) Inspection fixtures and special handling tools
2) Manufacturer's instructions, drawings and specifications for the test item
3) Applicable previous test results
4) Theoretical studies and calculations for the test item

b. Select the tests to be conducted and the test parameters for the individual tests according to the criteria of APPENDIX A and the individual MTP's.

c. Formulate the operating test plans.

d. Prepare a test log book for recording all pertinent information and results.

6.1.1 Preparation of Test Item

Perform the following:

a. Inspect the test item to ensure that it conforms to the manufacturer specifications and that it is free from damage due to transport and/or handling.
b. Photograph the test item during the pre-test inspection to document its received condition.
c. Record the following for the test item:

1) Nomenclature
2) Model number
3) Serial number
4) Manufacturer
5) Physical characteristics, including:

a) Length
b) Height or diameter, as applicable
c) Width or diameter, as applicable
d) Weight
e) Center of gravity location

6) Damage or deficiencies noted during the initial inspection

6.1.2 Preparation of Equipment and Facilities

Perform the following for the applicable tests:

a. Prepare the testing facilities as described by the applicable MTP's.
b. Set-up the test instrumentation and data acquisition system as described by the individual MTP's.
c. Prepare the test fixtures, jigs and adapters as described by the individual MTP's.

6.2 TEST CONDUCT

Combined environmental tests shall be conducted in accordance with the latest revisions to military specification MIL-STD-810, or a variation of this specification, or according to applicable MTP's.

Standard laboratory and manufacturer's safety practices shall be followed to avoid injury to personnel and damage to the equipment.

Conduct the selected combined structural environmental tests on the test item, as applicable.

NOTE: In most environmental tests it is standard practice to subject the test item to the specified environment through each of 3 mutually perpendicular axes. Therefore, it is extremely important to thoroughly inspect the test item after each test phase so that failures may be isolated.

6.2.1 Vibration - Temperature Tests

Conduct the combined vibration-temperature tests as described by the applicable sections of MTP 5-2-507, MTP 5-2-583, and MTP 5-2-594, using the criteria of paragraph 2, APPENDIX C.

6.2.2 Vibration - Constant Acceleration Tests

Conduct the combined vibration-constant acceleration tests as described by the applicable sections of MTP 5-2-507, and MTP 5-2-586, using the criteria of paragraph 3, APPENDIX C.

6.2.3 Vibration - Aerodynamic Loading Tests

Conduct the combined vibration-aerodynamic loading tests as described by the applicable sections of MTP 5-2-504, MTP 5-2-507, MTP 5-2-587, and MTP 5-2-612, using the criteria of paragraph 4, APPENDIX C.

6.2.4 Vibration - Altitude Tests

Conduct the combined vibration-altitude tests as described by the applicable sections of MTP 5-2-507, MTP 5-2-582, and references 4E and 4H, using the criteria of paragraph 5, APPENDIX C.

6.2.5 Vibration - Shock Tests

Conduct the vibration and shock tests as described by the applicable sections of MTP 5-2-506 and MTP 5-2-507, using the criteria of paragraph 6, APPENDIX C.

6.2.6 Vibration - Acoustic Tests

Conduct the vibration-acoustic tests as described by the applicable sections of MTP 5-2-507 and MTP 5-2-508, using the criteria of paragraph 7, APPENDIX C.

6.2.7 Acoustic - Acceleration Tests

Conduct the combined acoustic-acceleration tests as described by the applicable sections of MTP 5-2-508 and MTP 5-2-586, using the criteria of paragraph 8, APPENDIX C.

6.2.8 Shock - Acoustic Tests

Conduct the combined shock-acoustic tests as described by the applicable sections of MTP 5-2-506 and MTP 5-2-508, using the criteria of paragraph 9, APPENDIX C.

6.2.9 Shock - Temperature Tests

Conduct the combined shock-termperature tests as described by the applicable sections of MTP 5-2-506, MTP 5-2-583 and MTP 5-2-594, using the critera of paragraph 10, APPENDIX C.

6.2.10 Shock - Acceleration Tests

As discussed in paragraph 11, APPENDIX B, shock-acceleration tests shall be conducted at a rocket sled test facility. MTP 5-1-029 describes rocket sled test facilities which are available to all DOD agencies, contractors and research organizations.

6.2.10.1 Pre-test Operations

Perform the following:

a. Using the criteria discussed in APPENDIX A, determine the rocket sled performance profile required to provide the required test parameters.
b. Make the necessary arrangements for the following:

1) Test scheduling at the selected facility
2) Test item transportation to the test facility
3) Test item installation on the sled
4) Instrumentation selection, installation and checkout
5) Selection of data to monitor during the test runs
6) Processing of preliminary data
7) Processing of final data

6.2.10.2 Test Operations

Perform the following:

a. Conduct the rocket sled tests according to the predetermined performance profile.
b. Inspect and photograph the test item at the conclusion of the run to determine any structural failure or physical damage.
c. Record all observations and the nomenclature of the affected parts.
d. Verify that the instrumentation is intact.
e. Repeat steps a through d until a minimum of 3 runs have been completed which closely approach the intended sled performance profile.

NOTE: Analysis of selected preliminary data shall be used to indicate whether or not a particular test run is satisfactory.

6.2.10.2 Post-test Operations

Perform the following at the conclusion of testing:

a. Conduct a complete inspection of the test item components and parts.

NOTE: X-ray inspection shall be used whenever necessary to complement the visual inspection.

b. Record all observations made.
c. Photograph parts which have failed or been damaged.
d. Record the nomenclature of the affected parts.

6.2.11 Constant Acceleration - Temperature Tests

Select the method of testing from the following, using the criteria of APPENDIX A, from the following:

a. Centrifuge method
b. Rocket sled method

6.2.11.1 Centrifuge Test

Conduct the combined constant acceleration-temperature tests as described by the applicable sections of MTP 5-2-586, MTP 5-2-583 and MTP 5-2-594, using the criteria of paragraph 12, APPENDIX C.

6.2.11.2 Rocket Sled Test

Conduct the combined constant acceleration-temperature tests as described by the applicable sections of MTP 5-2-583, MTP 5-2-594, and as described in paragraph 6.2.10 of this MTP, using the criteria of paragraph 12, APPENDIX C.

6.2.12 Aerodynamic Heating - Aerodynamic Loading Tests

Conduct the combined aerodynamic heating-aerodynamic loading tests as described by the applicable sections of MTP 5-2-509, MTP 5-2-594, MTP 5-2-504, and MTP 5-2-612, using the criteria of paragraph 13, APPENDIX C.

6.3 TEST DATA

6.3.1 Preparation for Test

Record the following for the test item:

a. Nomenclature
b. Model number
c. Serial number
d. Manufacturer
e. Length in inches
f. Height or diameter in inches
g. Width or diameter in inches
h. Weight in pounds
i. Center of gravity location in inches from a reference point (missile body station, etc.)
j. Damage or deficiencies due to transport or handling

6.3.2 Test Conduct

6.3.2.1 Vibration - Temperature Tests

Record data as collected under the applicable sections of the following:

a. MTP 5-2-507
b. MTP 5-2-583
c. MTP 5-2-594

6.3.2.2 Vibration - Constant Acceleration Tests

Record data as collected under the applicable sections of the following:

a. MTP 5-2-507
b. MTP 5-2-586

6.3.2.3 Vibration - Aerodynamic Loading Tests

Record data as collected under the applicable sections of the following:

a. MTP 5-2-504
b. MTP 5-2-507
c. MTP 5-2-587
d. MTP 5-2-612

6.3.2.4 Vibration - Altitude Tests

Record data as collected under the applicable sections of the following:

a. MTP 5-2-507
b. MTP 5-2-582

6.3.2.5 Vibration - Shock Tests

Record data as collected under the applicable sections of the following:

a. MTP 5-2-506
b. MTP 5-2-507

6.3.2.6 Vibration - Acoustic Tests

Record data as collected under the applicable sections of the following:

a. MTP 5-2-507
b. MTP 5-2-508

6.3.2.7 Acoustic - Acceleration Tests

Record data as collected under the applicable sections of the following:

a. MTP 5-2-508
b. MTP 5-2-586

6.3.2.8 Shock - Acoustic Tests

Record data as collected under the applicable sections of the following:

a. MTP 5-2-506
b. MTP 5-2-508

6.3.2.9 Shock - Temperature Tests

Record data as collected under the applicable sections of the following:

a. MTP 5-2-506
b. MTP 5-2-583
c. MTP 5-2-594

6.3.2.10 Shock - Acceleration Tests

Record the following for each test item:

a. Data as collected by the test facility for each rocket sled test run
b. Rocket sled test facility identity
c. Run number (1, 2, 3, etc.)
d. Results of all post-run and post-test observations and inspections
e. Nomenclature of parts affected by failure and/or damage

6.3.2.11 Constant Acceleration - Temperature Tests

6.3.2.11.1-Centrifuge Test

Record data as collected under the applicable sections of the following:

a. MTP 5-2-586
b. MTP 5-2-583
c. MTP 5-2-594

6.3.2.11.1-Rocket Sled Tests

a. Record data as collected under the applicable sections of the following:

1) MTP 5-2-583
2) MTP 5-2-594

b. Record the following for each test item:

1) Data as collected by the test facility for each rocket sled test run
2) Rocket sled test facility identity
3) Run number (1, 2, 3, etc.)
4) Results of all post-run and post-test observations and inspections
5) Nomenclature of parts affected by failure and/or damage

6.3.2.12 Aerodynamic Heating - Aerodynamic Loading Tests

Record data as collected under the applicable sections of the following:

a. MTP 5-2-509
b. MTP 5-2-594
c. MTP 5-2-504
d. MTP 5-2-612

6.4 DATA REDUCTION AND PRESENTATION

The data produced by the procedures outlined in this MTP shall be reduced, analyzed and presented as required by the MTP's applicable to the individual tests and shall especially be in accordance with the methods, procedures and criteria of MTP 5-1-025.

The log book or folder containing pertinent information concerning the combined testing program shall be complete, accurate and up-to-date, to ensure its usefulness in future analyses of equipment and system reliabilities.

Upon the termination of a test due to test item failure, it shall be coordinated with the final results and conclusions and recommendations concerning the suitability of the test item for service use and compliance with the design specifications shall be submitted.

The test results shall:

a. Establish the test item performance expectancy and level of reliability.
b. Provide a history of test environments that can be used to provide test parameters in future testing programs.
c. Provide an indications of future problem areas for similar equipment.
d. Provide a basis for design changes specifications which must be met by any retrofit or modification programs set up for the test item.
e. Aid in predicting possible damages which may occur to the test item if it were subjected to other environments.
f. Provide the basis for the evaluation of the test item with respect to the manufacturer's specifications and/or the military requirements imposed by its intended use.

All photographs, movies, and other illustrative material resulting from the test, shall be properly identified and retained as part of the permanent test log.

The final data from rocket sled tests shall be presented in tabular form. Graphical presentation shall be used to show the resultant sled performance profiles in comparison to that originally planned for the tests. The data processing facility at the rocket sled test site may be used to process the test data as required by the test plan.

APPENDIX A

TEST PARAMETER CRITERIA AND SELECTION

1. INTRODUCTION

Although the performance and reliability of a component or system might be predicted, only extensive tests under the environments, or combination of environments, actually anticipated will confirm the attainment of the required reliability, or else show that redesign is required. Tests under simulated environmental conditions can give practical assurance that the reliability is adequate.

Decisions must be made from a considerable number of choices, for formulating test plans and selecting the test parameters. These choices exist within certain problems. The problems principally are:

a. Level of breakdown of the tests
b. Selection of test environments
c. Construction of the detailed test plans

2. LEVEL OF BREAKDOWN

The decision on the equipment level at which to perform the tests is made individually for the item under consideration, often partly on the basis of earlier environmental tests. Sometimes tests might be made at the system level, or at the sub-system level, or at the component level, or at the part level.

The advantages of testing at high levels are:

a. The results already account for possible interactions among the different parts of the equipment.
b. Less total testing will be required at high levels of breakdown, if reliabilities are to be demonstrated. Aside from the fact that low level tests are by-passed, the demonstration of a low reliability (corresponding to a high level of breakdown) requires either a fewer number of units (attribute items) or fewer test hours (time items). Table A-I illustrates this point with an attribute item and the statistical approach. First if the demonstration is to be carried at part level, then 46,052 systems will have to be tested. If the system is tested as a whole only 45 system tests would be required.

TABLE A-I

ILLUSTRATION OF TESTING REQUIRED FOR DEMONSTRATION OF RELIABILITY AT DIFFERENT LEVELS OF BREAKDOWN

Test Level Of Item	No. Of Items	No. Of Parts Per Item	Reliability Of Item To Get 0.95 Sys. Reliability	REQUIRED TESTING FOR DEMONSTRATION			
				No. Tests Per Item	Total No. Tests	Total No. Parts	Total No. Equivalent Systems
Part	1000	1	0.99995	46,056	46,052,000	46,052,000	46,052
Component	100	10	0.99948	4,428	442,800	4,442,800	4,428
Sub-System	10	100	0.99483	445	4,450	445,000	445
System	1	1000	0.95000	45	45	45,000	45

NOTE: System to consist of 1000 distinct parts. Reliability of 0.95 to be distributed equally among the items. Zero failures to be allowed among the test units. Demonstration to show at 90% confidence level that the required reliability is at least attained.

The advantages of testing at low levels of breakdown are:

a. Weakness can be detected, isolated and corrective action taken much more quickly since the results are not obscured by the effects of other equipment.

b. Greater flexibility is available to attain fiscal design since:

1) Reliability testing may begin sooner.
2) System design is not too far committed.

c. Test equipment can be smaller and thus offer more chances of adequate test facilities being available.

3. SELECTION OF ENVIRONMENTS

The second problem facing the environmental tester is the selection of test environments. Not all possible environments are able to be simulated and not all tests are able to be performed under environments which can be simulated. Discretion is required. The experience of the design engineer is utilized to help select the test environments corresponding to the predicted operating environment in which the equipment appears to be particularly vulnerable. The three phases of environmental concern are:

a. Transportation
b. Storage

c. Operational use

The environments, whether applied singly or in combinations, can also be applied to a test level in an environmental test specification such as outlined in MIL Specifications. The level of environments, whether individually specified or arbitrarily set, should at least be equal to the level set by the environmental design criteria and, preferably, should be slightly beyond. Composed according to the statistical design of experiments, test plans using individually specified environments can provide for the evaluation of single environments as well as the interactions among the environments. Test plans which utilize environments specified as test levels provide for the evaluation of the effect of the test level as a whole rather than the single effects and interactions.

Other sources from which the test parameters may be selected are:

a. Theoretical calculations - where computer studies are run from updated inputs based on previous evaluation programs. A variety of combinations can be programmed and investigations carried out emphasizing particular conditions with respect to others. Theoretical calculations are especially useful when key experimental data are not available.

b. Statistical calculations - studies where computer calculations are based on experimental data or on previously calculated theoretical data.

c. Experimental data - analyses of prior results from the testing of prototype designs, simulated sections and especially designed scale models in facilities such as wind tunnels, high temperature laboratories, aerodynamic chambers and the like can be used to determine the parameters. Aerodynamic data are generally provided by the results of specialized experiments, usually with a high degree of validity.

d. In-service measurements - the gathering of data from operational simulations and flight testing offer a primary source of test parameter information. However, the overall program must be well past its initial stages before such data becomes available. Methods of obtaining and analyzing data of this type are described in MTP 5-1-025.

4. CONSTRUCTION OF THE DETAILED TEST PLANS

Test plans will usually be limited by factors outside statistical considerations which could include:

a. Funds allotted for test units

b. Availability of the test facilities

c. Current limitations of the test equipment for simulating the conditions

d. Manpower required to carry out the tests

Test plans embodying the statistical design of experiments can also be employed. The advantages of such plans are that the interaction effects, in addition to main effects, and they are generally efficient from the standpoint of the gain of information per unit tested. The analysis of the results usually depends upon the assumptions that:

a. The errors are distributed normally.

b. The total effect is the sum of the individual effects and interactions plus an error term.

If the first assumption is not fulfilled, a transformation can be made so that it will be fulfilled. Factorial designs, where the effects of two or more factors are found are also able to be used. Fractional factorial designs can be used to reduce the number of test units required but with some sacrifice of information on possible interactions. An example of the use of fractional factorial designs applied to environmental tests can be found in reference 4.I, along with other environmental plans. Test methods and instrumentation planning are also discussed in reference 4.I. Since the final test plan is left to the discretion of the testing agency, and depends on the test parameters as well as other factors previously discussed, reference material can provide solid help in its develcpment.

APPENDIX B

SPECIAL FACILITIES, EQUIPMENT AND INSTRUMENTATION

Whenever possible, tests shall be conducted using the specified test facilities and equipment that are available since these have been proven effective through previous use. However, some combined environmental tests may require special facilities and equipment.

In order that combined shock-acceleration environmental tests may be conducted, it is necessary to utilize a rocket sled test course. Rocket Sleds are designed and used to conduct tests at speeds and accelerations not obtainable from other moving carriers that may be instrumented and recovered. Further details pertaining to the design and use of a rocket sled test course are discussed in MTP 5-1-029.

To perform combined environmental tests when one of the environments to be evaluated is the temperature environment, it is recommended that a hot and/or cold climate chamber be utilized. This type facility is equipped with conditioning machines which control the temperature within reasonable limits for a relatively long period. Further details pertaining to the design and use of hot and/or cold climate cells or chambers are discussed in MTP 5-2-502.

A reverberation chamber may be used in conducting combined acoustic-vibration environmental tests. This chamber is designed with highly sound-reflective surfaces that are nonparallel. Baffles are arranged in the acute corners to resist the formation of standing waves. Further details pertaining to the design and use of a reverberation chamber are discussed in MTP 5-2-508.

Combined structural environmental tests usually are conducted in laboratories especially equipped for this purpose. The test being performed and the specimen under test will determine the specific instrumentation requirements. Typical test equipment includes:

a. Vibration exciters, mounting fixtures, transducers, and accelerometers. Details can be obtained from MTP 5-2-507.
b. Impulse shock machines, ballistic pendulum shock machines, air-operated shock machines, and free-fall shock machines. Details can be obtained from MTP 5-2-506.
c. Pneumatic and electrodynamic acoustic drivers. Details can be obtained from MTP 5-2-508.

In addition, instrumentation required for measuring aerodynamic heating and loading can be obtained from the aerodynamic test MTP's. Structural data analysis instrumentation requirements can be obtained from MTP 5-1-025.

APPENDIX C

COMBINED STRUCTURAL ENVIRONMENTAL TESTING

1. INTRODUCTION

There is an increasing need to provide design engineers, and others interested in determining whether an item of equipment can withstand adverse environments with more information on the behavior of components and systems under a combined environmental profile. Thus it is necessary to design and build suitable "laboratory" testing facilities which will provide a wide range of combined environments, including temperature, acceleration, vibration, simulated altitude, shock, aerodynamic loading and acoustic noise.

There are many different approaches to the solution of problems associated with combined environmental testing. Some of these approaches are presented in the text of this appendix, while various others can be found in the applicable references. For example, instrumentation procedures for missile and equipment testing are described in MTP 5-1-028.

2. VIBRATION - TEMPERATURE TESTING

Combined vibration-temperature tests are perhaps best conducted by using an exciter which has been designed to operate at extreme temperatures. Economically, however, this may prove to be unfeasible, unless the test specimen is extensively tested, due to the high cost of heating and/or cooking fluids.

Normally, it is undesirable to place an exciter into extreme temperature environments, unless the unit has been designed for that purpose. Usually, the fixture used for the vibration input to the test item, is subjected to the test temperature environment on one end, and to the ambient temperature on the other. With high thermal gradients across the fixture, the accompanying thermal stress results in a change in its response characteristics.

The problem of temperature differentials may be overcome, to a limited degree, by installing insulating materials between the test fixture and the exciter. Hard insulating material such as fiberglass phenolic or metal sandwich sections with refrasil or other insulating material between the outer faces can be used.

There are some disadvantages in using insulating material such as:

a. Sealing of the conditioning shroud is more difficult.

b. True vibration effect may not be transmitted through the insulating material without power reduction or distortion of the input vibration.

Another method of overcoming the temperature differential is to suspend the test specimen with rubber cords (Bungee shock cord), inner tubes, or other appropriate soft suspension methods. A vibration exciter is placed outside of the conditioning shroud and the vibration input is transmitted through a drive rod that is suitably attached to the test specimen.

Figures C-1 and C-2, illustrate two typical test-setups for a remote vibration-temperature test. In Figure C-1, number (1), indicates the conditioning equipment; number (2) is the input and output for the conditioned air; number (3) indicates the soft suspension method employed; number (4) is the conditioning shroud; and number (5) indicates two of the four vibration exciters used in this test.

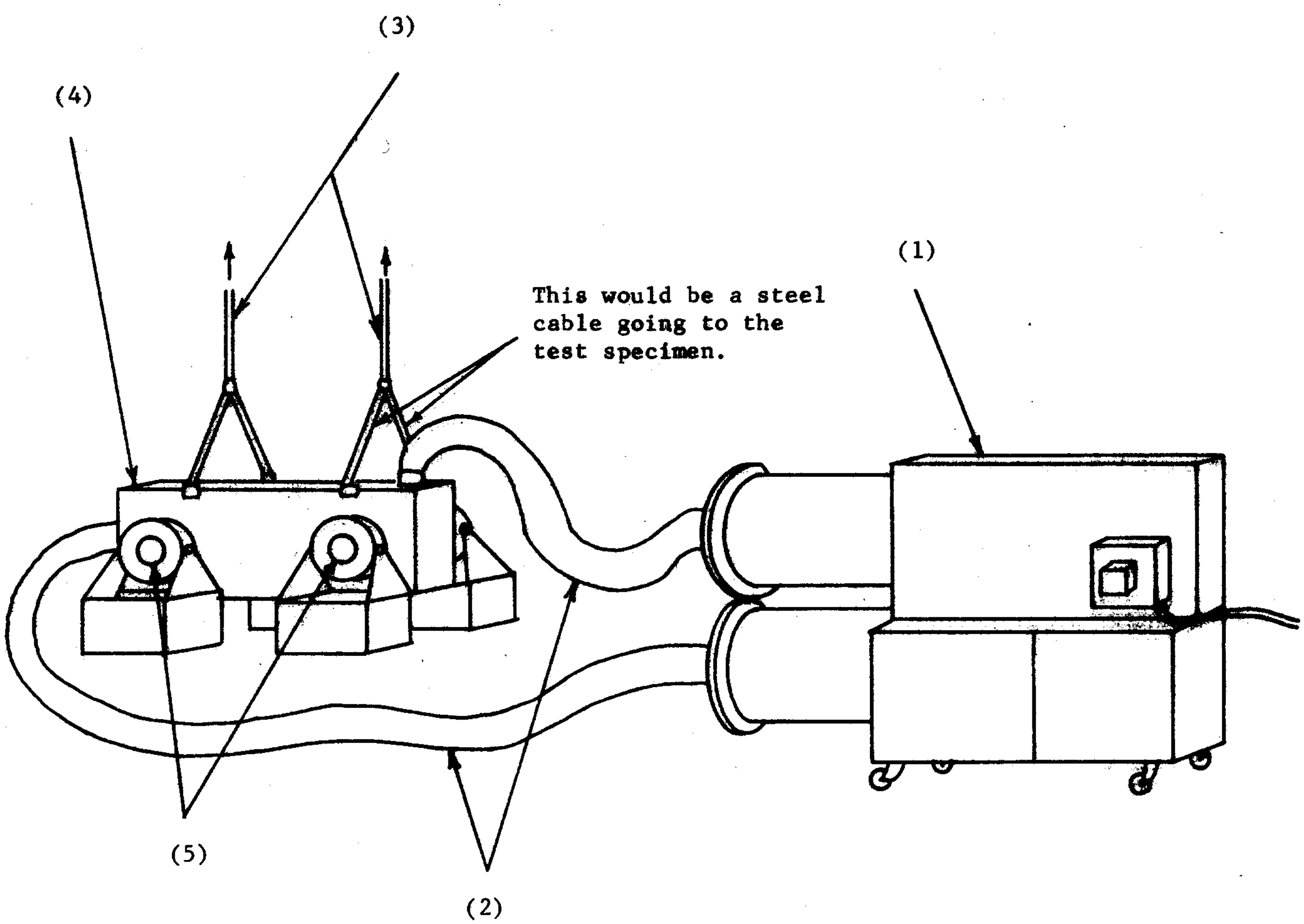

Figure C-1 Typical Vibration-Temperature Test Set-up

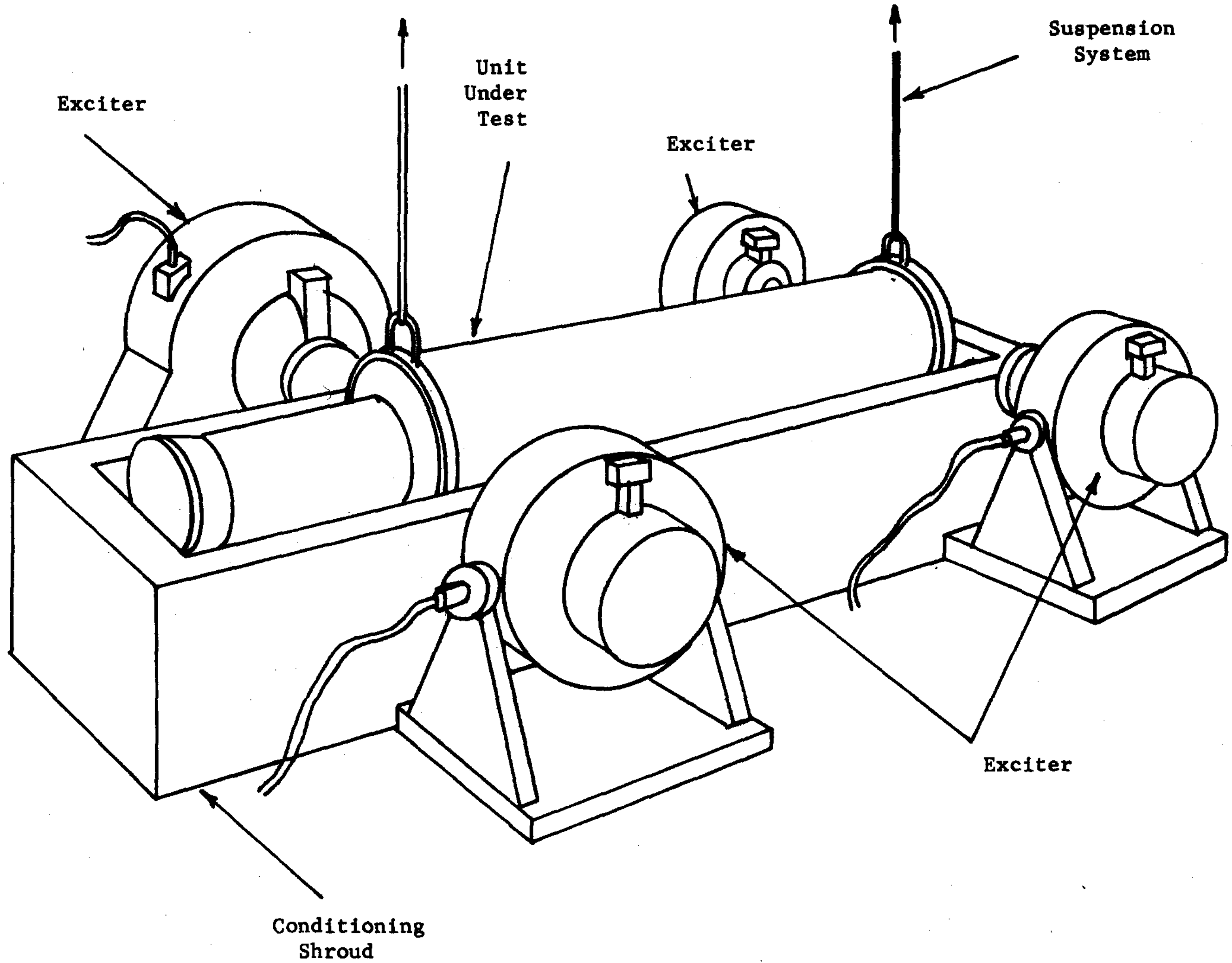

Figure C-2 View of the Four Vibration Exciters, the Test Specimen and the Conditioning Shroud with the Top Removed

If accelerometers and pressure transducers are used during the vibration-temperature test, the data obtained must be corrected or otherwise accounted for by calibration of instruments to allow for the effects of temperature. It is recommended that all accelerometers, transducers, and other associated test equipment be temperature compensated and calibrated at the test temperature. If the test requires various test temperatures, calibration should be accomplished at each temperature.

Bonded strain gages cannot be calibrated in the manner recommended for accelerometers and transducers. Strain gages from the same package or manufactured lot can be mounted on the same type of material that the test specimen contains and subjected to the same temperatures at which the test will be conducted. Before and after each test, the strain gages can be exposed to a known strain and the system calibrated.

Few problems will be encountered during the vibration-temperature test if the temperature environment remains constant throughout the test. If gradient temperatures are encountered, the resulting data may be compromised and the possible error factor increased.

Further details and discussions concerning extreme temperature testing can be found in MTP 5-2-583, MTP 5-2-593, and MTP 5-2-594. Vibration testing is documented in MTP 5-2-507.

3. VIBRATION - CONSTANT ACCELERATION TESTING

Vibration-constant acceleration testing, usually, is accomplished by mounting an electrodynamic vibration exciter on a centrifuge. Modification of the vibration exciter is necessary so that it will withstand constant acceleration in the axis parallel and normal to the exciter table motion. The two major problem areas are:

a. Maintaining the proper exciter armature alignment during the test so that the vibration direction is normal to the centrifuge arm.

b. Keeping the total weight of the test specimen, vibration fixtures, and the exciter armature multiplied by the constant acceleration g level (dead weight) within the shaker capability, where the direction of vibration is parallel to the constant acceleration axis.

To avoid these problems, modify the exciter by designing and installing new flexures which will maintain the armature in a position that is within the required tolerance. Problems also may be avoided by attaching air springs to the centrifuge arm and to the vibration fixture. The force taken up by these air springs should be variable and reasonably close to the equivalent dead weight. The air springs should have a natural frequency that is outside the test frequency range and should be designed to produce a minimum damping force.

The coriolis acceleration effect in the vibration-constant acceleration test can normally be neglected so long as:

a. The vibration amplitude is small compared to the length of the centrifuge arm.

b. The weight of the arm and the exciter field is large compared to the weight of the armature fixture and the test specimen.

Further discussion of coriolis effects in combined environmental testing is given in reference 4 I.

Since the vibration produced by the exciter may adversely affect the centrifuge, an effort should be made to isolate the exciter from the centrifuge. This may be accomplished by designing a suspension system that will effectively isolate the exciter from the centrifuge over the frequency range of the test.

Vibration-constant acceleration testing may be successfully combined with temperature, altitude, and/or humidity environmental tests. Consult Reference 4.G, for further details concerning modification of the exciters, design of a suspension system, and conduct of vibration-constant acceleration tests in combination with other environments.

4. VIBRATION - AERODYNAMIC LOAD TESTING

Combined vibration and aerodynamic loading tests are frequently performed to verify the structural integrity of missile air frames subjected to various modes of vibration. This type of testing has become increasingly important in recent years due to the demands for increased speed and maneuverability in missiles.

The test configurations and equipment required for this type of testing will vary from simple jigs, simulating longitudinal thrust and vibration, to elaborate hydraulic and/or pneumatic systems necessary for the simulation of dynamic load encountered in a high g turn. Simulation of the combined vibration-static loading requires test setups similar to those discussed in MTP 5-2-504 and MTP 5-2-507. The objective of this particular type of testing is to determine the transmissibility of vibrations to various missile components during launch.

Data acquisition for these tests is usually accomplished through the use of piezo-electric type accelerometers and strain gauges in accordance with MTP 5-1-025, However, techniques utilizing photo-stress methods and laser beams can be employed to acquire the structural data if the degree of sophistication requires these methods. A discussion of the photo-stress method of data acquisition is given in MTP 5-2-587.

The major problem in this type of combined testing is isolating the vibration exciter from any applied transverse load, either as an input during the test, or as the result of a failure. In many tests it is possible to design the input rod from the exciter to serve as a failure link, which fails in the event that the precalculated transverse load is exceeded. This, however, is often not possible, as for example, in a test that might require an exceptionally long input rod from the exciter. Again the condition exists where the input rod has high strength characteristics in tension and compression but fails under a slight bending load. The rod, due to its required length, must be a stiff member and therefore, cannot be machined as a failure link without compromising its rigidity.

Studies, currently being conducted, indicate a possible solution to this problem lies in the use of viscoelastic materials. Exploratory tests have shown that adequate vibratory energy can be transmitted through layers of viscoelastic materials having suitable properties, even at frequencies higher than the natural frequency of vibration of the system. Refer to MTP 5-2-507 and to MTP 5-2-612 when preparing for a combined aerodynamic loading and vibration test.

It is recommended that all data obtained from tests of this type be recorded on magnetic tape so that analyses of the results from the combined environments may be more easily correlated with regard to event versus time. Readily available data recorded on a direct writing oscillograph are also desirable so that continuous observations of applied loads may be made.

5. VIBRATION - ALTITUDE TESTING

The most frequently used method for accomplishing a vibration-altitude test is to place the test specimen and the exciter in an altitude chamber. References 4.E and 4.H describe the use of an exciter and an altitude chamber in performing tests of this type. Care must be exercised in the selection of transducers and other exposed instrumentation. Instruments used must be accurate and reliable at simulated high altitudes to ensure the validity of the acquired data. Further discussion of tests conducted at simulated altitudes may be found in MTP 5-2-582.

6. VIBRATION - SHOCK TESTING

It is generally considered that testing of this combination of environments is not feasible and should not be conducted simultaneously. Since the vibration and shock tests are both quite complex, require extensive instrumentation, and may cause many problems, they should be performed independently, using MTP 5-2-507, and MTP 5-2-506.

7. VIBRATION - ACOUSTIC TESTING

The measurement of each environment in this combined test is difficult and, in many cases, the data are inseparable. For example, vibration measuring transducers may produce a signal as a result of the acoustical field. In addition, the acoustical field can cause vibration of light weight panels and items that are not mounted rigidly. Although such vibration actually is present, it is not a response of the vibration environment. The measurement of the acoustical field is a measurement of the acoustical noise generated by the acoustic test combined with a sinusoidal (discrete frequency) vibration test, the acoustical measurement would reflect a white noise field of a higher level at discrete frequencies that are a result of the vibration environment. White noise occurs when the power of a random vibration signal is uniformly distributed throughout the frequency domain.

The effect of an acoustical environment on a vibration exciter is negligible except when low level vibration is combined with a high level acoustical field. The problem of interaction between the exciter and the acoustical drivers normally will be minor. The physical presence of equipment normally not installed in a reverberation chamber may change the noise field and create an over or under test condition with respect to the acoustical field. It is a normal procedure to install a minimum of equipment in the reverberation chamber to minimize reflection or absorption of the acoustical field. It is recommended that the vibration exciter be located outside of the chamber during this test. However, if this is not possible, it is recommended that the noise field be carefully measured with the exciter inoperative. Changes in the acoustical field may then be determined, by comparison, with the exciter operating.

The error caused by the effect of the acoustical field on the vibration transducers can be minimized by measuring the signal produced by the transducer when it is subjected to the acoustical field, or by isolating the transducer from the acoustical field. The control of the vibration input is from a vibration monitor installed at an input point to the test specimen or on the exciter table. Details concerning an acoustical environment, instrumentation, methods, and procedures for conducting this type of test are discussed MTP 5-2-507 and MTP 5-2-508.

8. ACOUSTIC - ACCELERATION TESTING

The methods for providing an acoustical field when a test specimen is mounted on a centrifuge, are to excite the complete centrifuge enclosure or to use a reverberation chamber that can be mounted on the centrifuge table. Of these two methods, the latter is more advantageous. It would eliminate the problems of uncontrolled reflections of the acoustical field from the centrifuge pit walls, uncontrolled change in the acoustic field due to the large rotating mass, and high velocity air movement caused by the centrifuge. Acoustic, pneumatic or electrodynamic drivers may be mounted and operated on the centrifuge. Fewer drivers will be required if a reverberation chamber is mounted on the centrifuge table.

Test procedures are described in the applicable sections of MTP 5-2-508 and MTP 5-2-586.

9. SHOCK - ACOUSTIC TESTING

Shock-acoustic tests tend to present the same type of problems which are associated with vibration-acoustic tests. The requirement for a large isolated mass for the shock machine (as in the case of a free-fall shock tester) presents an installation problem since, presumably the shock testing equipment would be installed within a reverberation chamber. The nature of the test and the test specimen may, however, make the use of a ballistic pendulum shock tester, or a pneumatic shock tester more feasible. The latter types of equipment are physically smaller, easier to install and provide a lesser degree of disturbance to the acoustical field than a free-fall shock tester.

Detailed descriptions and discussions of acoustic and shock testing procedures are contained in MTP 5-2-508 and MTP 5-2-506.

10. SHOCK - TEMPERATURE TESTING

This type of combination testing may be conducted using laboratory shock testing machines or may be conducted using procedures described in rough handling simulation tests where the test item is placed in its shipping container and dropped from a given height onto a steel or concrete pad or a similar hard surface.

Generally, the problems which may be encountered and the instrumentation requirements for this combination of testing are similar to those discussed under vibration-temperature testing. Procedures for conducting and instrumenting

these tests can be found in MTP 5-2-506, MTP 5-2-583, MTP 5-2-594 and MTP 5-1-025.

The use of impulse shock machines for testing small components will tend to simplify this test (depending on the test requirements) since the mounting surface (table) is small and usually will not be affected by extreme temperatures. Proper conditioning is easily accomplished.

Testing of larger components on free-fail shock machines usually requires that the conditioning shroud be mounted on a drop table and allowed to experience the test shock along with the test specimen, or the shroud may be removed just prior to the drop. Removal of the shroud may subject the test specimen to an unsatisfactory temperature gradient, making this procedure undesirable, unless a well-chosen preconditioning program is used. If the extra weight and the additional transient vibrations produced by the shroud do not compromise the test results, dropping of the conditioning shroud with the test specimen is probably best. If the presence of gradient temperatures is not significant, the shroud may be removed. The effects of extreme temperatures on the drop table and the fixture must be considered and any resultant change in waveforms must be evaluated prior to using either test method.

A rough handling test of containers is relatively simple since fixtures are not required. The test specimen usually is allowed to free-fall onto a concrete pad or concrete block and the shock environment is measured. The impact surface, container, and the test specimen may be temperature conditioned and the test conducted in a hot and/or cold test chamber. Figures C-3, C-4 and C-5, illustrate a typical test setup for three different rough handling tests conducted in a hot chamber. These setups would be similar if the tests were conducted in a cold chamber.

11. SHOCK - ACCELERATION TESTING

A test of a specimen in this combination of environments will require the use of a rocket sled. The shock environment is produced with water brakes of auxiliary boosters depending on the test requirements in simulating the actual environment.

Among the unique capabilities of rocket sled testing is that conditions are produced which certain types of information available, since the sled very closely simulates the rugged environment of missile boost. For "sustained" periods of time (10 to 25 seconds) the following data may be obtained with large scale or full scale models:

a. Aerodynamic effects

1) Lift
2) Drag
3) Aerodynamic pressure (shock waves)
4) Aerodynamic heating
5) Aerodynamic vibration (flutter)

b. Acceleration (linear)

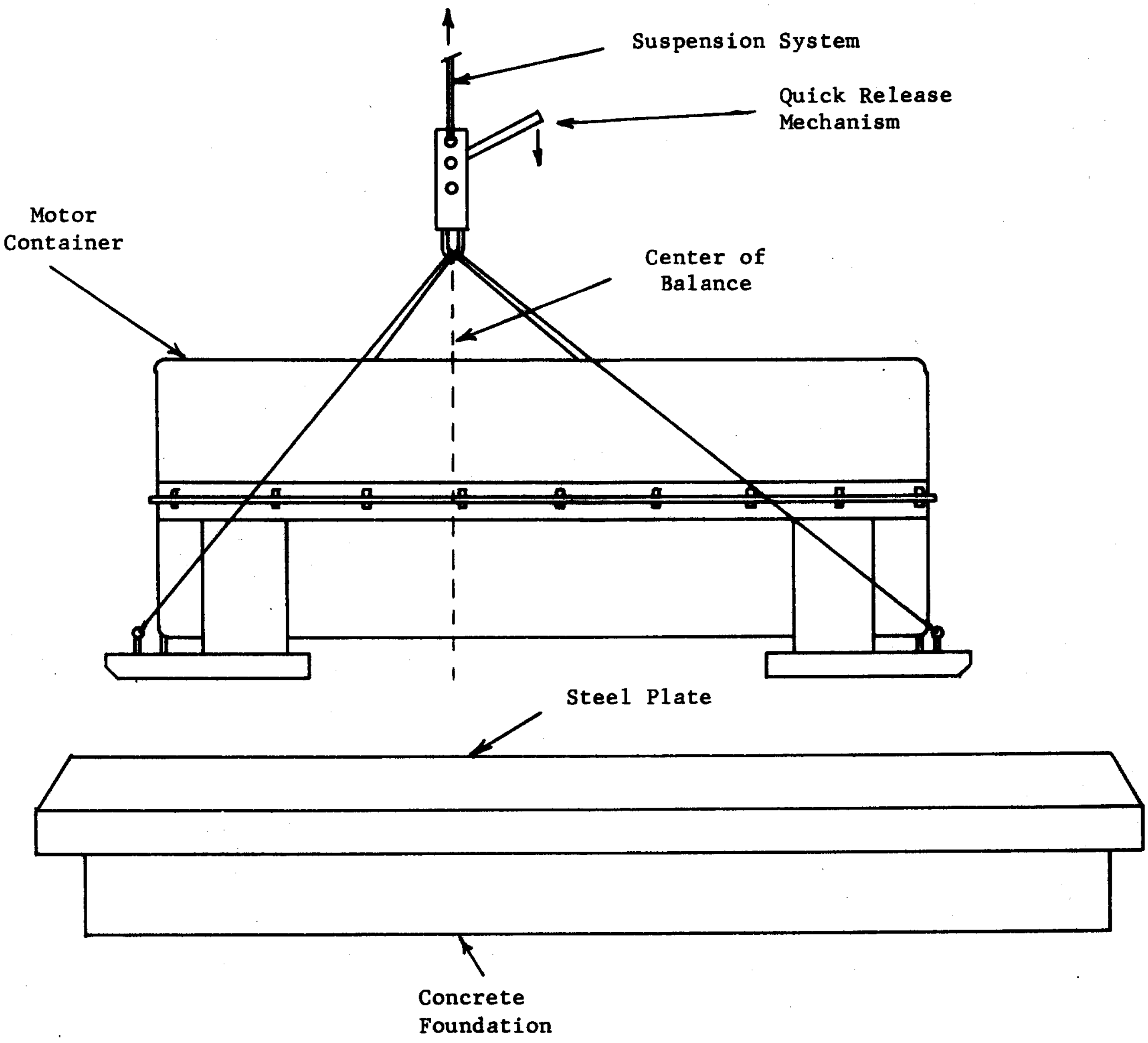

Figure C-3 Typical Setup for a Flat Drop of a Container (after thermal conditioning)

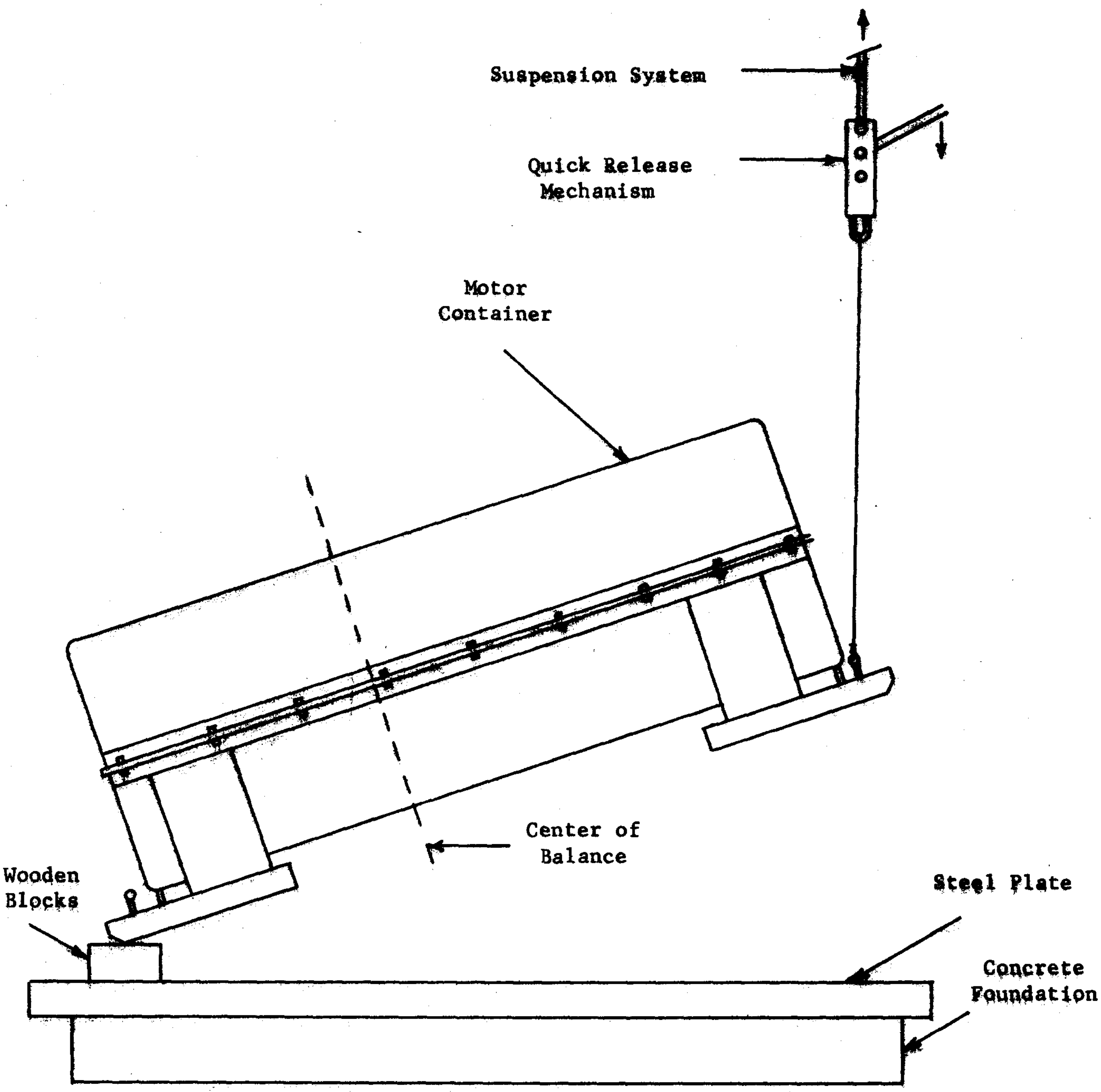

Figure C-4 Typical Setup for an End Drop Test
(after thermal conditioning)

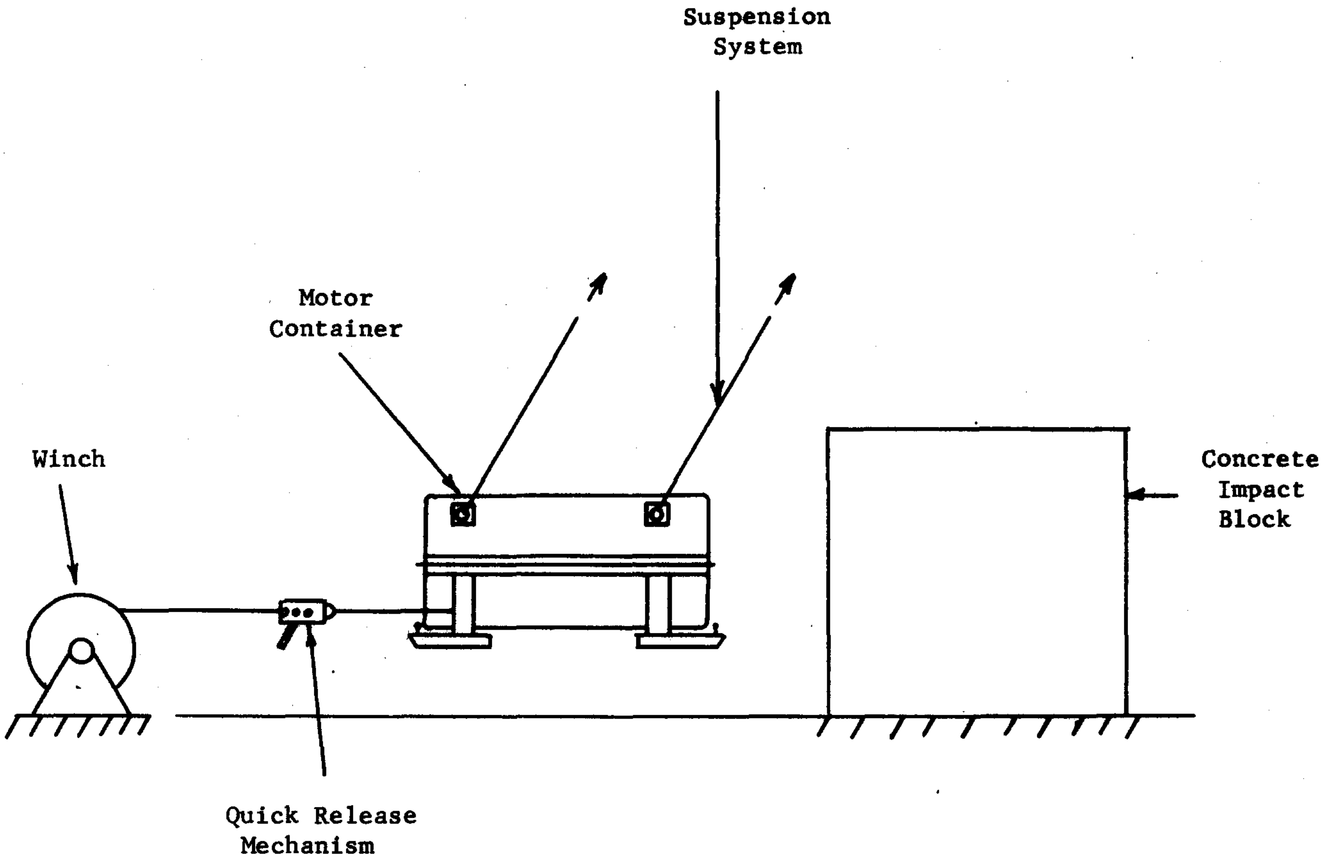

Figure C-5 Typical Setup for a Pendulum-Type Impact Test
(after thermal conditioning)

c. Deceleration or impact (linear)
d. Velocities

Discussions of rocket sled facilities and the techniques used in conducting sled tests can be found in reference 4.H, and in MTP 5-1-029. Telemetry methods for data retrieval are described in MTP 5-1-028.

12. CONSTANT ACCELERATION - TEMPERATURE TESTING

A constant acceleration-temperature test may be accomplished by placing a conditioning shroud on a centrifuge table or on a rocket sled and piping conditioned air into the shroud as discussed in paragraph 2 of this appendix. When a stable temperature is reached, the air input and outlet ducts are removed and the holes sealed just prior to the acceleration phase of the test. Thus the temperature gradient should be minimized during acceleration.

The shroud must be stong enough to withstand the test acceleration and should be insulated on all sides. It should also provide for mounting the test specimen on the floor or rear wall of the shroud, as the situation requires. The weight and size of the shroud will decrease the capabilities of the centrifuge in terms of the weight and size of the test specimen. The shroud weight and wall thickness should be minimized. In the case of high acceleration where the centrifuge table reaches high angular velocities, the shroud should be designed to minimize drag.

Addtional information concerning the procedures and instrumentation for this combination are described in MTP 5-2-586, MTP 5-2-583, MTP 5-2-594 and MTP 5-1-029.

13. AERODYNAMIC HEAT - AERODYNAMIC LOAD TESTING

Close simulation of an environment which combines aerodynamic heating with aerodynamic loading demands elaborate facilities and instrumentation. Generally, a dynamic testing cell where the pressures, temperatures, vibrations and shocks of a missile flight phases can be reproduced simultaneously, is required. In addition, a rapid data acquisition system, is a must, since long setup times dictate that as many tests per setup configuration be conducted, as feasible. Preliminary data retrieval must be fast to provide the basis for valid test parameter changes.

The major problem in conducting a combined test of this nature is the effect of heat on the test stand and the instrumentation. A protection scheme for instrumentation protection must not interfere with the test specimen, yet must also protect fragile wiring and delicate measuring devices from pressure and vibration environments.

While the facilities for aerodynamic testing of missiles exist in numerous places throughout the country the facility requirements are dictated by the test parameters. Discussions and descriptions of aerodynamic testing may be found in MTP 5-2-509, MTP 5-2-512, MTP 5-2-612 and in MTP 5-1-025.